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Lubrication

A Technical Publication Devoted to the Selection and Use of Lubricants

THIS ISSUE

Diesel Engine Wear—Its Cause and Prevention

PUBLISHED MONTHLY BY

THE TEXAS COMPANY

TEXACO PETROLEUM PRODUCTS

THE DIESEL ERA

THE development of the Diesel engine over the past decade has been most interesting and an outstanding feature of engineering research and design. As a result, today the Diesel has emerged out of an era of experimentation, as a most practical and efficient type of prime mover. The extent to which it has been adopted for marine propulsion, and the extent to which accuracy of sailing schedules is being maintained indicates the dependability of this unit.

In the stationary power plant field, it is notably efficient. Yet, with all its efficiency, the Diesel has problems of operation. Among those which are of particular interest to the petroleum industry are the reduction of wear through the maintenance of effective lubrication and the freedom from troublesome deposits through the choice of a suitable lubricant.

In this issue, we hope to create a better understanding of the cause and prevention of wear and deposits.

The Texas Company has been closely identified with the development of the Diesel from its very early stages. As a matter of fact, when the Diesel might be said to be making its debut in Europe and was still in the nature of a "mechanical curiosity" in the United States, Texaco engineers had already developed an efficient and highly satisfactory Diesel lubricant. It was called Texaco URSA Oil and was the forerunner of the Texaco line of Diesel lubricants.

Texaco URSA Oils are known the world over. They are distinguished for certain qualities which have made for them an invaluable reputation on land and sea.

An Outline of the qualities which make Texaco URSA Oils particularly suitable for Diesel lubrication follows. They

1 Burn cleanly,

2 Lubricate thoroughly,

3 Form a minimum of gummy deposits,

4 Lend themselves to the most complete cleaning and reclamation,

5 Are absolutely uniform, regardless of where or when they may be obtained,

6 They form a minimum of hard carbon deposits,

7 Show pour tests which will be commensurate with the storage and operating temperatures, and sufficiently low to not cause clogged oil piping,

8 Have adequate viscosity to meet the bearing pressures,

9 Maintain effective cylinder compression and a protective film of lubricant on all wearing surfaces during operation and stand-by.

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THE TEXAS COMPANY

Texaco Petroleum Products

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Diesel Engine Wear—Its Cause and Prevention

THE life of any piece of mechanical equipment depends largely upon the extent to which wear is prevented between its moving parts. As a result, every effort should be made to prevent or reduce wear as far as possible.

In the operation of the Diesel engine, the most successful way to extend the life of the bearings and cylinder liners is by means of proper lubrication. It is important to remember, however, that this will only hold true just so long as there are no structural imperfections which may be the original cause of wear, and which cannot be remedied by means of lubrication.

As a result, other things being equal, wear will decrease according to the extent to which the rubbing surfaces are separated by a suitable lubricating film. As a general rule, by virtue of the nature of their construction and operation, such a separation of wearing surfaces can be more readily accomplished in bearings than in the other wearing parts.

Bearings permit of a more complete realization of perfect lubrication; cylinders, on the other hand, are at best perfectly lubricated in the coolest portions only, and ordinarily are but incompletely separated from the piston rings by a very thin and discontinuous oil film.

It is important to remember, however, that no matter how good a lubricant may be or no matter how judiciously it may be applied, it cannot materially reduce excessive wear which may be the result of structural or mechanical faults. As yet, designing engineers have failed to completely develop all the exact causes of excessive wear. In consequence, the nearest approach to the general solution of the problem is to give adequate consideration to the possible effects of wear on all the mechanical parts involved.

POSSIBLE CAUSES OF WEAR

It is generally agreed upon by operating as well as designing engineers that cylinder wear especially is dependent upon the nature of combustion and fuel quality. The effect of improper lubrication on wear is more or less obvious. It is also believed that piston and piston ring design, materials of construction, as well as the pressures and temperatures existing within the cylinders, will have definite effects on wear. For an engine possessing a long working stroke, the position of the oil feeds for cylinder lubrication is also of considerable importance.

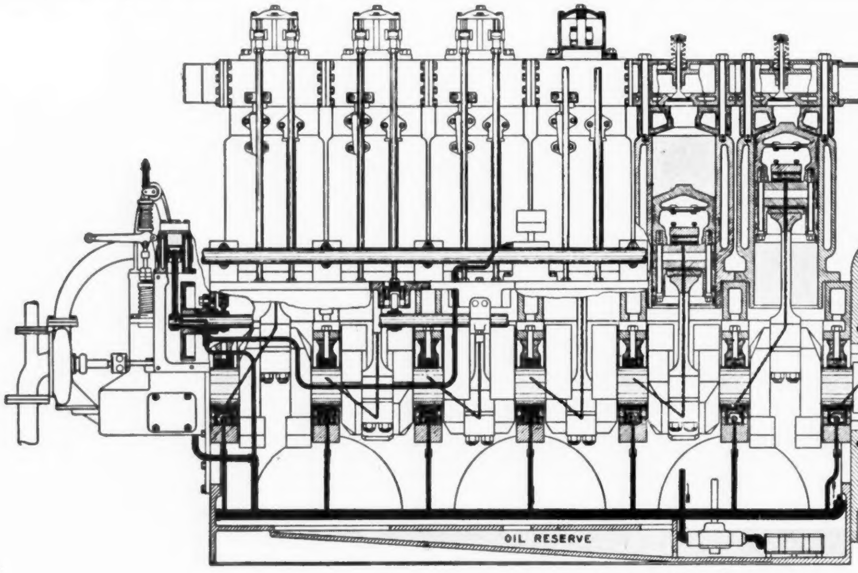
Incomplete Combustion

As was mentioned above, improper combustion may affect wear. Whatever the cause of improper combustion, the result will be that all of the fuel supplied to the combustion chamber is not actually burned. The unburned portions of the atomized fuel will be caught by the thin oil coating on the cylinder walls, or else tend to creep past the piston rings to eventually reach the base, wherever the design makes this possible.

In the first case, the quality of the lubricant

in the base will be lowered, thus leading to excessive bearing wear. In the second case, the quality of the cylinder lubricant may suffer due to change in viscosity or due to the content of solid matter.

Abnormally high cylinder temperatures are undesirable, since due to excessive expansion, they lead to increased wear and may even cause seizure. Such temperatures furthermore decrease the volumetric efficiency of the engine, which, of course, means a direct power loss.



Courtesy of Ingersoll-Rand Company

Fig. 1—Lubricating diagram of Ingersoll-Rand locomotive oil engine. Oil piping and flow to the various bearings is shown by heavy black lines.

Fuel Quality

Ash content in the fuel is another cause of excessive wear. Ash is the non-combustible mineral matter dissolved or suspended in the fuel. After combustion, a considerable portion of this mineral matter will exist in the form of an extremely fine powder capable of being swept out and carried along by the exhaust gases. Some of it will be caught in the lubricating oil films, thus impairing lubrication and increasing wear. But, however serious wear may be due to excessive ash content, it certainly cannot be held responsible for the fact that cylinder liners do not wear uniformly, but instead, show maximum wear some four to ten inches from the top.

Cylinder Wear

This is a most interesting feature of cylinder wear. As a matter of fact, maximum wear will occur somewhere within the first ten inches from the top of the liner, to rapidly decrease as the lower ends of the liners are reached.

It is significant that the zone of maximum wear is developed where maximum pressure and temperature exist in the cylinder and where the piston speed is lowest. The exact reason for this is not quite understood, but it seems reasonable to expect a metal which is heated and stressed to its elastic limit to wear more than one which is stressed to a much less degree.

It has been found in practice that wear and revolutions per minute seem to be almost directly related. That seems reasonable, since one may expect more metal to be worn off when the surfaces are gliding past another 1000 times a minute than if they are moving past one another at but half this rate. In the estimation of some designing engineers, increased piston speed would tend to an equalization of wear.

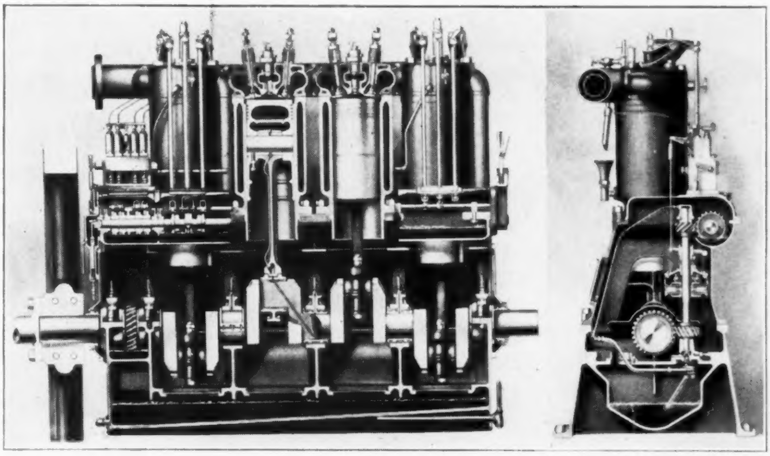
The effect of gas pressure on wear has been the subject of frequent investigation. It has been demonstrated that considerable pressures exist behind the upper rings, pressing them out with considerable force against the cylinder walls.

One of the most promising explanations offered for the increase in wear due to high pressures, deals with the eroding action of hot gases moving at high velocities. The only fallacy of that explanation, however, is that if cylinder wear is solely due to the eroding action of the hot gases moving past the rings the wear should be circular, while in reality the wear is almost always elliptical. In a large number of cases, where such data were available, it was found that the major axis of the ellipsis of wear was at right angles to the plane in which the connecting rod moves.

Pistons and Piston Rings

As to the effect of piston and piston ring design on wear, it is to be pointed out that recent practice places the first ring quite some distance below the top of the piston. The reason for doing this is to give the gases that may pass the ring a chance to cool off somewhat, thus decreasing the temperature at the most likely point of maximum wear.

The vertical clearance allowed for the rings also seems to be a contributing factor. Too small clearance results in undesirable restraining of the rings from their natural motion. Too small end clearances may also cause the rings to expand longitudinally on heating, and frequently to buckle. Excessive clearance on the other hand, is thought to permit the full gas pressure to get behind the rings and thus increase wear.



Courtesy of Chicago Pneumatic Tool Co.

Fig. 2—Sectional view of the Chicago Pneumatic four-cycle solid injection Diesel engine, showing oil piping, governor, linkage and lubricating oil pump.

But if some wear of the cylinders is due to the eroding action of the hot gases, it is reduced by the expedient of placing the first ring at quite some distance from the top of the piston. In many cases, this distance will correspond to one-quarter of the piston diameter. The required number ordinarily becomes larger as the size of the piston is increased, primarily due to the difficulty encountered in fitting the rings.

Spacing of the first ring away from the top of the piston will bring it closer to the cooling medium, and further away from the flame, thus permitting it to be better lubricated. This then means less tendency to gumming up, better seal for the gases and general increase in life.

Excessive wear, however, may also be due to poor liner material. The best material to be used generally is the result of actual trials over long periods, and metallurgical research. It appears that no definite material has yet been universally employed.

As stated above, the wear of liners and rings is affected by engine cooling, lubrication and the quality of combustion. While in the smaller size engines the pistons are sufficiently cooled by the inrushing air for combustion, there seems to be a definite size beyond which additional cooling has to be provided in some form.

Wear of Main Bearings

The evils and undesirable consequences of excessive bearing wear may be as serious as those of excessive cylinder wear or even more so. While cylinder wear, in extreme cases, leads to loss in compression and consequent loss in power, excessive main bearing wear in addition to loss in power may also lead to fracture of the crank shaft.

Bearing troubles are not always apparent or audible. In a two cycle, single acting engine, for instance, where the load on a bearing is always in one direction, that is, downward, quite a bit of wear may exist without any audible signs, while in the four cycle engine, comparatively smaller amounts of wear may be indicated by pounding at the end of the exhaust stroke.

Crank Shaft Failure

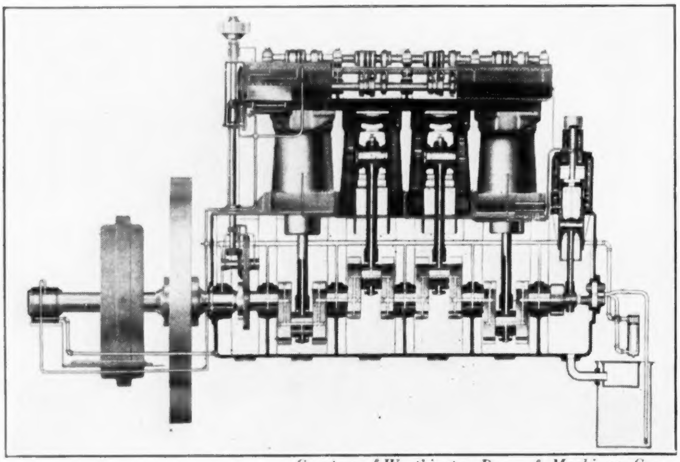
Crank shafts may break when the stresses they are subjected to are not the ones for which they are designed. Unequal wear in the main bearings causes alternate bending of the shaft in opposite directions, which eventually may lead to failure of the shaft as a result of fatigue.

Deflection of the bedplate also is a frequent cause of crankshaft failures where the foundation is not rigid. No matter how massive they appear, bedplates will deflect under the stresses they are subjected to. Arrangement and the amount of cargo in a ship may also cause such undesirable deflections. Improper installation, of course, is a common source of bedplate trouble on both land and sea.

Still another source of crankshaft failure is torsional vibration, which will become very destructive under certain conditions. Proper design can reduce torsional vibration at operating speeds to a minimum.

IMPORTANCE OF PROPER COMBUSTION

Combustion is a chemical reaction which takes place between the atomized fuel and the oxygen of the air. Chemical reactions require certain definite proportions of the combining substances in order that the reactions may be complete.



Courtesy of Worthington Pump & Machinery Corp.

Fig. 3—Lubricating oil system of the Worthington four-cycle air injection Diesel Engine. Bearings and gears are pressure-lubricated by a geared pump, driven from the main crank shaft.

This at once suggests that, for correct combustion, a certain amount of fuel requires a very definite amount of air. It is not only necessary to have the proper amounts of air and fuel present, but it is almost just as essential to have them so well mixed that maximum contact between fuel and air exists. This, of course, means proper atomization.

Whenever there is an excess of fuel over air, or in other words, a shortage of air, incomplete combustion will be the result. This means that some of the fuel will not serve its purpose.

Troubles Due to Incomplete Combustion

Incomplete combustion represents a wasteful use of the fuel. It will result in loss of power. When incomplete combustion is due to blocked exhaust ports, over-heating will take place. This may cause the rings to expand and break. High temperatures, of course, also lower the effective life of the lubricant, which eventually results in excessive wear.

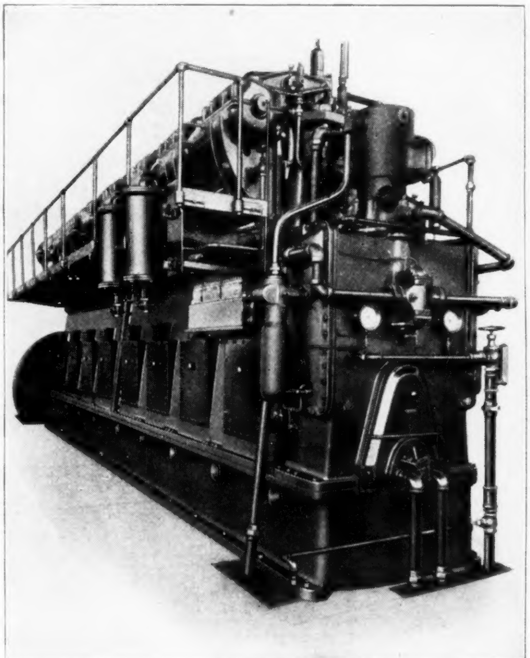
Furthermore, a certain amount of unburned carbonaceous matter may remain in the cylinders. Some of this will be caught by the lubricating oil film on the cylinder walls to cause excessive wear. There will also be a tendency for some of the unburned carbonaceous matter to work past the piston rings and finally find its way into the lubricant in the base, wherever such a possibility is not guarded against in the design. Thus, it can be readily seen that incomplete combustion, in addition to representing a direct power loss, will also cause indirect loss due to excessive wear.

Low Volumetric Efficiency

Anything that will tend to decrease the volumetric efficiency will result in incomplete combustion. Furthermore, undue restriction in the path which the air must follow will result in a lower volumetric efficiency.

Resistance of this nature may be the result of inadequate piping for the air intake, too many crooks and bends, or an improperly designed air filter. In consequence, one of the prime requirements an air filter has to meet is low resistance to flow of air.

Abnormally high cylinder temperatures decrease the volumetric efficiency and shorten the life of the lubricant.



Courtesy of Fulton Iron Works Co., Inc.

Fig. 4—End view of the Fulton Diesel engine. Both power and compressor cylinders are lubricated at two points on each cylinder by an automatic sight feed lubricator. The bearings and gears are also pressure lubricated.

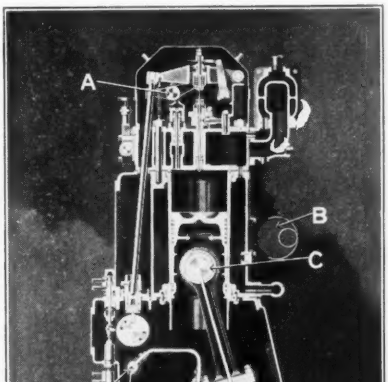
Air for Combustion

A correct supply of air is just as essential for satisfactory engine operation as a correct fuel supply. Air may carry impurities such as suspended dust which must not be permitted

to enter the combustion space. Installation of some device designed to remove this dust from the air is, therefore, incorporated in almost all well designed Diesel units, especially on land. The use of such air purifying devices is absolutely necessary where only dusty air is available.

Any foreign matter carried along into an engine during the suction or scavenging period may become one of the main causes of fouled valves and excessive wear of piston rings and cylinders.

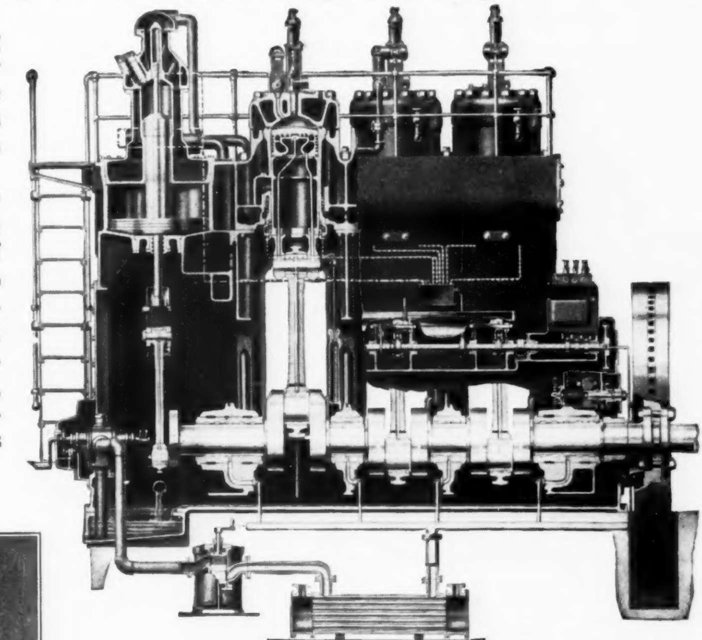
There are several types of air filters upon the market. Any such device to be successful must, of course, be efficient in its ability to remove all foreign matter completely. However, as already pointed out it must not offer too much resistance to the flow of inrushing air, since that would impair the volumetric efficiency, resulting in troubles explained above.



Courtesy of The Cooper-Bessemer Corp.

Fig. 5—Showing the type E. P. Bessemer Diesel engine. This is a high-speed machine, with all moving parts enclosed. "A" indicates force feed through hollow rocker shaft to top of pushrod and down pushrod to guide. "B" indicates lubricating oil cooler. "C" indicates where oil passes up hollow rod to full floating piston pin. "D" indicates force feed to cam shaft bearings. "E" is the main lubricating oil feed header and "F" the return oil outlet.

The distinctive features which should be investigated in choosing an air filter are: ease of cleaning, compactness, low first cost and low operating cost. Of the representative types of commercial air filters available at the present time, some rely on centrifugal force created by a rotary motion imparted to the air stream for purification; in others, the air is passed through dry felt, while still others involve passage of the air stream through steel wool covered with a substantially non-evaporating dust catching fluid, such as light lubricating oil.



Courtesy of Nordberg Manufacturing Co.

Fig. 6—Showing the oil circulating system on the Nordberg Diesel engine. Dotted lines show mechanical lubrication of power and air compressor cylinders. Bearings are pressure lubricated.

METHODS OF FUEL INJECTION

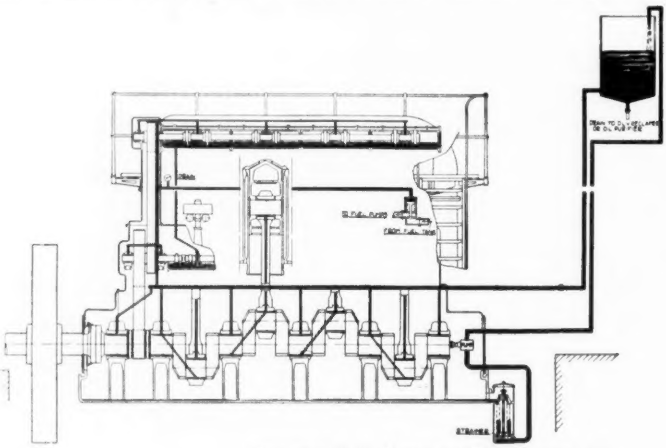
Fuel is injected into the Diesel engine either alone, as in the solid injection type of engine, or in company with compressed air. The earlier Diesel plans called for injection of fuel alone. It was developed later, however, that compressed air made a very good means of atomizing the oil sufficiently to develop instantaneous combustion. The extent to which this air should be compressed was found to depend upon the grade and the viscosity of fuel oil, the load carried by the engine and the design of the atomizing equipment.

Atomization is the result of the friction developed by the high relative velocities between oil and compressed air. In certain air injection engines, air and fuel are mixed and caused to flow through passages of decreasing areas in the nozzle. Highest velocity and highest degree of sub-division exists at the orifice or narrowest point. The fuel particles attain colloidal dimensions and flow into the compressed air of the combustion chamber.

In solid injection engines, the fuel is injected under high pressure and with a high swirling motion into the still and compressed air of the combustion chamber. The impact with this

air causes the oil to be more completely atomized.

In the solid injection of liquid fuel into the oil engine, one of three procedures may be followed. Either the oil is pumped to the fuel valves under sufficient pressure to effect atomization, being subjected to combustion in measured quantities when the above valves are opened for admission; or a separate plunger pump can be used for each cylinder, such a pump serving to meter out the requisite amount of fuel and deliver it at the necessary pressure; or a central pump with a distributor can be used.



Courtesy of I. P. Morris and De La Vergne, Inc.

Fig. 7—Line view of the De La Vergne Diesel engine, showing oil flow to bearings and other parts in heavy black lines. Note location of fuel and lubricating pumps, strainer and drain to oil reclaimer or purifier.

Importance of Proper Atomization

Poor atomization, as was pointed out before, will result in poor contact between air and fuel, and consequently, an incomplete interaction between them. As a result, not all the air will become available for all the fuel. Atomizing nozzles may become deficient as a result of incrustations which will force the fuel spray to travel in an undesirable direction and possibly penetrate too far.

In extreme cases, wet fuel may hit the cooler metal walls. This may lead to deposition of liquid fuel on the walls. Such liquid deposits eventually will contaminate the lubricating oil, which in turn may lead to extreme wear and incomplete combustion, due to the impaired volumetric efficiency.

Improper Functioning of Valves

For an engine to work efficiently it has to receive the proper amount of fuel at a very definite point in the cycle. This point is definitely fixed by the valve actuating mechanism. If this mechanism, for any reason, should cease to cause fuel injections at the proper moment, loss in efficiency, partly due to incomplete combustion, may result.

FUELS

It is a distinct feature of Diesel engines that they may be designed to operate on a large variety of fuels of mineral or vegetable origin. The final selection of a particular fuel should be prompted by cost considerations only. It may, for instance, be cheaper to operate the engine with a low grade, unrefined fuel and to replace the liners once a year than to operate with a refined fuel and to replace the liners only once in five years.

Fuel Requirements

To be suitable, a Diesel engine fuel must meet the following requirements, viz.: It should be

1. Of sufficient fluidity to enable easy pumping throughout the system without the necessity for preheating.
2. Free from sediment or any other impurities which might clog the strainers, pump valves, fuel injection valves, piping, nozzles or orifices according to the type of engine, or cause excessive cylinder wear.
3. As free as possible from water inasmuch as this latter will not only tend to interfere with ignition, but furthermore, lower the calorific value of the oil.

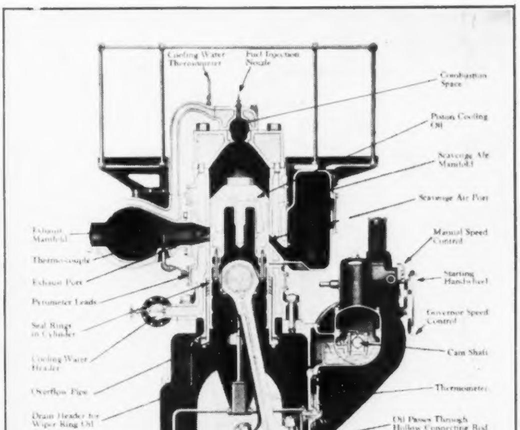
Courtesy of McIntosh & Seymour Corp.

Fig. 8—Showing a McIntosh & Seymour four-cylinder double-acting Diesel engine. Note location of mechanical force feed oilers for cylinder lubrication.

4. Of as low a sulfur content as possible, to avoid any chance formation of corrosive acids within the engine. Where fuel oils contain an abnormal percentage of sulfur this latter may have an especially deleterious action on exhaust passages, corroding and causing leakage in many instances, depending, of course, upon the extent to which the metal corrodes, the presence of moisture and the chemical form in which sulfur exists in the oil.
5. Refined to a sufficient extent to bring about the removal of highly volatile hydrocarbon fractions which, under the ordinary conditions of storage and handling, might vaporize and render the fuel unduly hazardous due to the generation of inflammable mixtures with air.

Petroleum Fuels

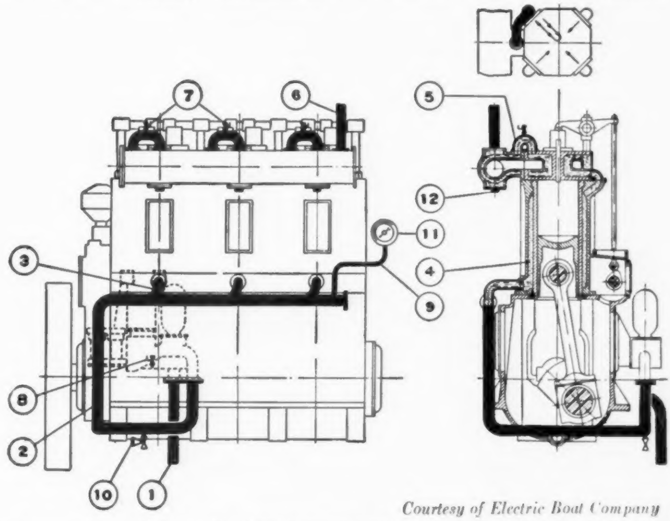
The first and apparently the most adaptable type of fuel is of mineral origin. Whether time will prove this statement remains to be seen. However, from a practical point of view, such fuels are most abundant in most localities at prices commensurate with those of coal. Therefore, oil engines generally are designed to burn them in preference to other products, which, of course, might give quite as good results, but which are economically more or less out of the question.



Courtesy of Fairbanks, Morse & Co.

Fig. 9—Transverse section of a Fairbanks-Morse Diesel engine showing details of lubricating and cooling water systems.

In the combustion of this type of fuel, ignition in the present type of oil engine is more readily attained, by reason of the chemical characteristics, and the volatility at the operating temperatures.



Courtesy of Electric Boat Company

Fig. 10—Showing the water-circulating system of the Nelseco M.A.N. engine. (1) is pump suction pipe; (2) is pump discharge to cylinder jacket; (3) connection to each cylinder jacket; (4) circulation through cylinder and cylinder head jackets; (5) connection from cylinder head to exhaust-header jacket; (6) outlet from exhaust header; (7) vent cocks; (8) snifting valve on pump; (9) gauge connection; (10) drain valve; (11) pressure gauge; (12) drain plugs.

Coal, Tar and Benzol Products

In this group of valuable liquid fuels, products from bituminous coals such as coal tars and those other products from which benzol is derived are included. In general, it is interesting to note that such fuels do not ignite as readily as petroleum fuel in the average Diesel engine.

Furthermore, in many localities, their cost in comparison with petroleum oils is normally so far out of line that any attempt to adapt the oil engine to burn them would be economically inadvisable at this time. The opposite of this situation, however, may exist in some European countries.

Vegetable Oils

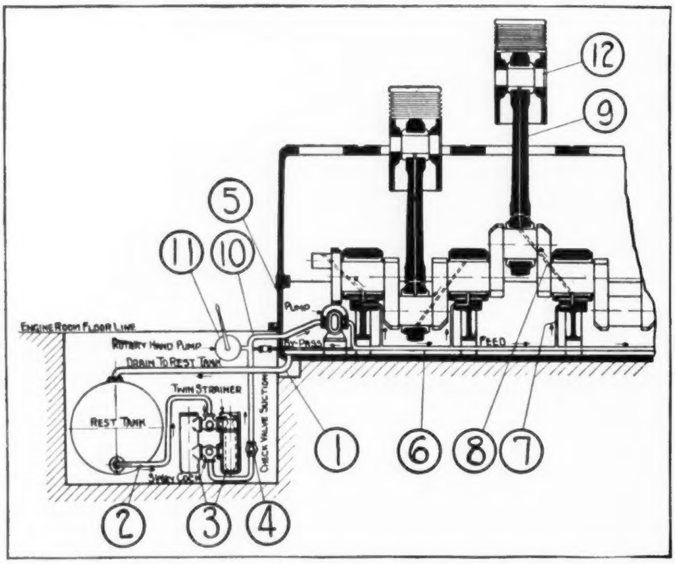
This third group is composed of vegetable oils such as the products from the castor bean, soya bean, cotton seed, peanut, etc. Certain of those have been used to some extent with more or less success in the tropics, where these oils would be more readily obtainable at fair prices. Here they might compete on more even terms with fuels of the first two groups.

But whatever the origin of the fuel used,

higher injection pressures will be required, the heavier and less volatile the fuel.

ENGINE COOLING

Perhaps the largest single factor which controls the successful operation of modern Diesels is the high working temperature which is characteristic of these engines. At the moment of combustion the metal walls of the combustion chamber are heated and stressed to almost their safe limits. Out of strength considerations, then, it becomes necessary to provide some means of removing heat from these parts in order to permit them to stand up under the stresses.



Courtesy of Busch-Sulzer Bros. Diesel Engine Co.

Fig. 11—Schematic chart of pressure lubricating system of the Busch-Sulzer Diesel engine. After flushing out bearings, lubricating oil collects in the bedplate and flows (1) into a large rest tank, where it releases the entrained air and the moisture which has condensed on inside of crank case. The water may be drained off. The pump draws oil from the rest tank (2) through either side of the twin strainer (3) discharging into a main header (6), with riser (7) at each main bearing, and passages in shaft (8) and connecting rod (9) leading directly to main bearings, crank pin and crosshead pin (for two cycle) or piston pin (12) for four cycle.

Excessively high temperatures lead to considerable wear, hence, effective cooling has to be provided in order to prolong the life of the engine. Possibly the most serious trouble resulting from high temperatures is the lowering of the volumetric efficiency which, as mentioned above, represents a direct loss in power.

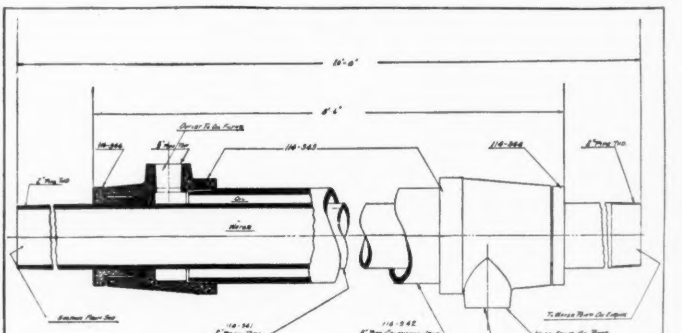
Cylinder Cooling

With the exception of the latest air cooled airplane Diesels, all such engines generally have water cooled cylinders. On account of the high temperatures encountered, it is essential to watch the nature of the cooling water. If the water is loaded up with suspended matter, insoluble salts, scale or muddy deposits will form on the cooling surfaces, thus impairing the rate of heat transfer. This, at once, results in higher cylinder temperatures and other undesirable consequences.

In localities where sufficiently pure water is not available, softening or purification will be necessary. Simple calculation will show that if a steady stream of impure water is passed through the cooling system virtually tons of solids would be passed through the jackets in the period of a year, of which some proportion would remain in the engine.

One common scheme of cooling is obtained by the use of a continuous circulating system. The heated water is cooled by spraying into air or by cooling with available cold impure water. The amount of evaporation taking place every time the water makes a complete round may amount to from three to five per cent. Hence, any such system has to depend on periodic make-up. It is best to have the make-up water of zero hardness, which would be obtained, for instance, by the use of a suitable water softener. In other cases, where the average water is not too hard, the make-up water need not be softened, and all of the water may be changed after a definite period of operation.

Recent experience, however, has pointed out that exposure of cooling water to the atmosphere is undesirable. Such practice permits the water to become charged with oxygen and invites corrosion troubles. The ideal arrangement would, therefore, seem to be a closed system, with the pure cooling water in



Courtesy of The Winton Engine Company

Fig. 12—Details of the Winton lubricating oil cooler.

turn cooled by an available supply of cold impure water.

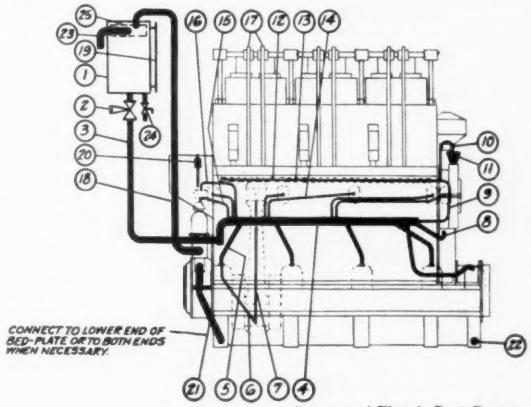
The same general precautions that are taken in the selection and treatment of boiler feed water should be taken in the selection of a suitable cooling water for Diesel engine service. Such efforts will always be well repaid, for the engine will be kept in a healthy condition for a much longer period of time.

Piston Cooling

In the smaller sizes, the pistons are sufficiently cooled by the scavenging air. However, as the sizes of pistons increase, a point is reached beyond which some additional method of cooling has to be provided. This is necessary in order to prevent excessive wear and possible seizing of the pistons. Furthermore, abnormally high temperatures may crack the piston top. Such pistons may be cooled by either oil or water.

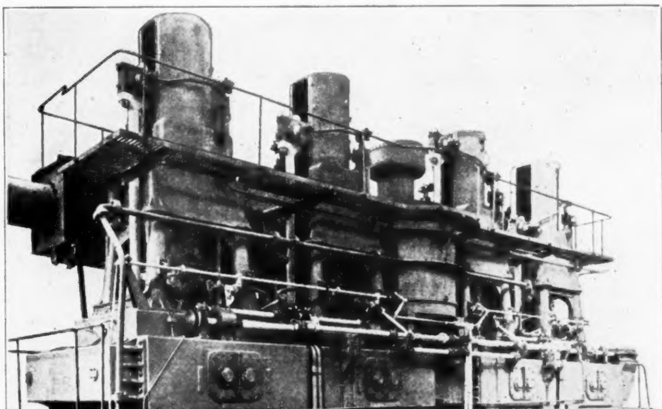
There are a good many arguments that may be advanced in favor of each of these cooling media. While oil has the lower specific heat, and thus a lower cooling capacity, on the other hand, it offers the distinct advantage that when leakage develops, it will not result in appreciable lowering of the quality of the base lubricant.

On the other hand the effectiveness of the best cooling oil is limited by the design of the piston. This latter should insure turbulence of flow and prevent as much as possible the formation of heat resistant films, otherwise carbon deposits may develop on the inside of the piston. Such deposits will naturally defeat the purpose to be accomplished.



Courtesy of Electric Boat Company

Fig. 14—Typical lubricating system for a Nelseco M.A.N. engine. (1) Gravity tank; (2) Gravity tank shut-off valve; (3) Gravity tank to header pipe; (4) Header; (5) Pipe to main bearing; (6) Hole through crankshaft to crank pin bearing; (7) Hole through connecting rod to wrist pin bearing; (8) Pipe to camshaft gear bearing; (9) Pipe to cam roller rocker shaft; (10) Sight over-flow pipe; (11) Sight over-flow funnel and oil bath for camshaft gears; (12) Hollow cam roller rocker shaft; (13) Holes to cam roller rockers; (14) Pipe to camshaft bearing; (15) Pipe to pump drive gears; (16) Pipe to camshaft shifting collar on reversing eng's only; (17) Grease cups for inlet and exhaust valve rocker arms; (18) Lift pump discharge pipe; (19) Gauge glass; (20) Oil cups for pump shaft bearings; (21) Lift pump suction pipe; (22) Plug; (23) Gravity tank over-flow to sump; (24) Gravity tank drain cock; (25) Removable strainer in gravity tank.



Courtesy of Sun Shipbuilding & Dry Dock Company

Fig. 13—Side view of an opposed-piston type, two cycle Sun Doxford oil engine. This engine is distinctive for the absence of valves; its direct reversibility, and the equalization of stresses and strains of operation.

Water, in turn, has a higher cooling effect, other things being equal. However, in the case of leakage, undesirable contamination of the base lubricant will result. The water too, of course, may lead to the formation of deposits on the inside of the piston if its nature is not closely watched. Here also design must maintain the water in a state of turbulent flow, in order to prevent the settling out of solids.

Exhaust Pipe Cooling

In general, the power out-put of an engine will be greater, the lower the pressure in the exhaust pipe. For that reason, means are provided in modern design to reduce the resistance to flow of exhaust gases, in order to lower the possible existing back pressures.

This means the use of sufficiently large pipe diameters and elimination of unnecessary bends. In most larger units, however, additional reductions in the exhaust line pressure are obtained by cooling of the gases.

LUBRICATION,—LUBRICANTS AND THEIR APPLICATION

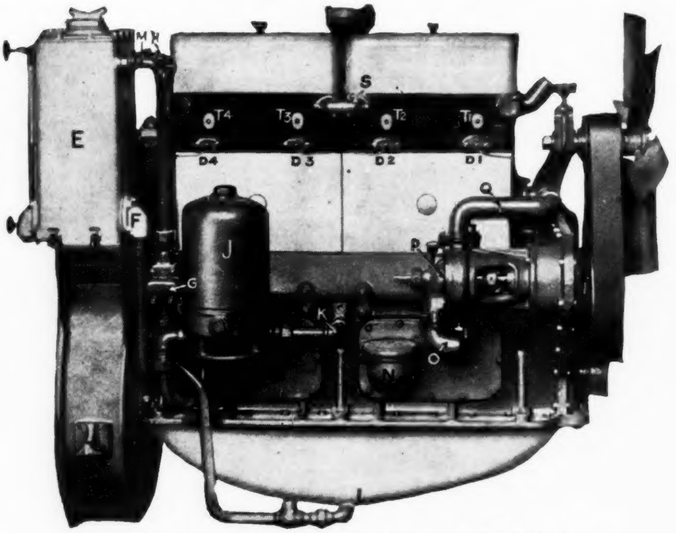
Quite frequently, the cause of breakdowns will be faulty lubrication. On engines of larger size, modern practice has adopted pressure feed lubricating systems for as many of the wearing and moving elements as possible.

In the absence of mechanical deficiencies, an engine will perform more satisfactorily and for a longer period of time when it is effectively lubricated. Conversely the best of design will be of little avail in lengthening the life of the engine if the quality of the lubricant and the method of its application are not properly studied.

Lubricating Oil Requirements

Regardless of whether a lubricant is to serve the engine cylinders or is to be used on the bearings, certain basic characteristics are necessary, viz.:

1. It must be so carefully refined as to be able to withstand the usual stresses and strains of intensive service. It should be carefully fractionated or the lighter components so effectively removed that it will not be so volatile as to require an undue quantity to maintain a suitable lubricating film, especially on the cylinder walls.
2. It should have as low an emulsification tendency as practicable, due to the chance of contact with water.
3. Furthermore, it must be of such a viscosity or body as to maintain a lubricating film of suitable thickness between the wearing surfaces, under the prevailing temperatures of operation. Yet it should never be so heavy or viscous at these temperatures as to give rise to abnormal internal friction within itself, for this might readily develop excessive operating temperatures especially on the engine bearings.
4. It should be sufficiently adhesive to resist being squeezed out from between the wearing surfaces when subjected to the normal pressures of operation.
5. It should not congeal at any of the lower temperatures to which it might be subjected during storage or operation. In this connection the pour test should be low enough to avoid the necessity for heating the storage tanks.
6. It should be capable of spreading readily over the wearing surfaces in the case of cylinder walls, not remaining in streaks or blotches for otherwise suitable sealing of the pistons might be impaired.
7. It must show as little carbon residue as possible, inasmuch as the decomposition



Courtesy of The Buda Company

Fig. 15—Exterior view of a Buda M.A.N. engine. "E" is the storage tank for the dry sump lubricating system; "G" indicates two gear pumps; "J" is the oil filter; "K" the oil line to the crankcase, from whence it is delivered under pressure to the bearings. Oil does not remain in the oil pan but is drawn out through the screen at (L) up to the scavenging side of the oil pump (G). This delivers it to the top of the tank at "M."

which will occur when the oil is exposed to the intensive heat of combustion, will in the case of many oils develop a large amount of objectionable carbonaceous residuum. Furthermore, this latter should be capable of easy removal.

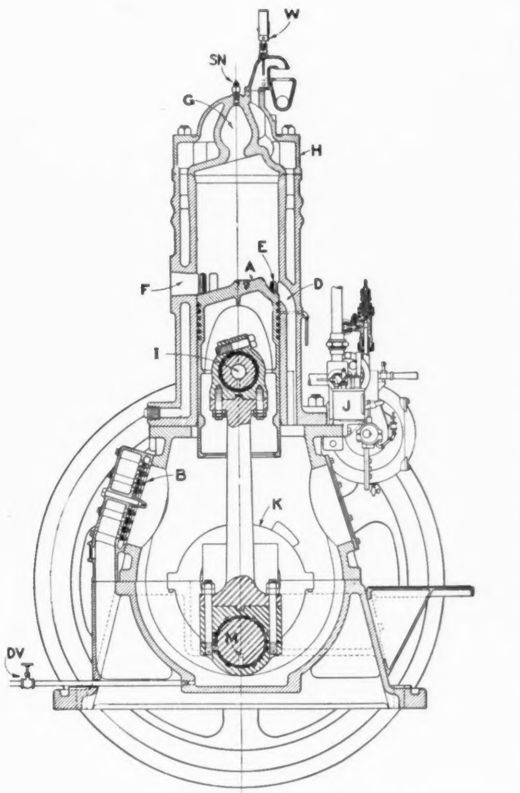
It should be fully appreciated that for an oil to meet all the above requirements careful attention is necessary, not only in refining, but also in transportation, storage and handling in the plant.

Cylinder Lubrication

Cylinder and piston wear are a common source of a great deal of trouble. Cylinder wear may result in loss of compression and drop in power. In other words, an engine with badly worn liners may be unable to carry full load. A most effective way by which excessive cylinder wear can be minimized is by use of proper lubricants, as well as dependable means of application.

The attitude of the designers in this matter is interesting. While some place the oil feed lines at a position somewhere in between the first two piston rings when the piston is at its lowest position, others locate the supply points somewhere above such positions. The goal desired in all cases, of course, is the attain-

ment of the lowest permissible oil consumption. The exact location of the oil feed to the cylinders represents the manufacturer's idea of just how this is best accomplished. Some designers have even gone so far as to synchronize the time of lubricating oil delivery with the lowest position of the piston.



Courtesy of Anderson Engine & Foundry Co.

Fig. 16—Cross section view of an Anderson oil engine. (A) is the Piston; (B) Air intake valve; (D) Transfer port; (E) Transfer port; (F) Exhaust port; (G) Combustion chamber; (H) Cylinder head; (I) Piston pin; (J) Lubricator; (K) Connecting rod lubricator; (M) Lubricating passage to crank pin; (W) Motometer; (DV) Base drain; (SN) Injector nozzle.

The comparatively large amount of wear which normally takes place in cylinders perhaps may be due to the fact that satisfactory lubrication of these parts is frequently difficult to attain.

Efficient lubrication of Diesel engine cylinders will also be influenced to a certain extent by the grade of the fuel and the completeness of combustion, as was pointed out before.

Experience has shown that lubrication should be positive and uniform, otherwise, rings will be worn and may even become stuck, with an appreciable loss in compression. The wrist pin, for example, will also be affected. This part on certain engines will be subjected to relatively high temperatures with but little opportunity for radiation of its heat, unless it is cooled mechanically.

While pistons generally rely upon a direct supply of lubricating oil, in some cases, however, they may be lubricated by a splash system. With the exception of small sizes where ring oiling and chain oiling are resorted to, all the larger sizes depend upon force feed systems for bearing lubrication.

Over-Lubrication

Over-lubrication leads to abnormal carbonaceous deposits in the cylinder, which may clog valves or ports. This effect is more pronounced in the case of the four-cycle than in the two-cycle engine. It seems that in the latter, the excessive oil is blown out through the exhaust ports.

Nevertheless, over-lubrication may result in a deposition of excessive amounts of carbonaceous matter near the exhaust ports. These deposits eventually may restrict the area of the exhaust, thus preventing proper scavenging. This means that some of the residual combustion products will occupy some of the volume which properly should be occupied by fresh air. This will, obviously, lower the volumetric efficiency. The result will be that cylinder temperatures may rise, lubrication will be impaired, wear will be increased, seizing of the pistons and loss of power may occur and there will, of course, be excessive lubricating oil consumption.

Bearing Lubrication

Under mechanically perfect conditions, such as in the case of correct alignment of the main bearings, comparatively little wear will take place in the engine bearings. This is primarily due to the fact that bearings, by virtue of their design and nature of operation, lend themselves to a more complete development of perfect lubrication; that is, a complete separation of the wearing members by a continuous oil film.

AIR COMPRESSOR LUBRICATION

In Diesel engine service, it is absolutely necessary that the air compressor be properly lubricated. By this we mean that it should be served with just the right amount of the most suitable grade of oil. Therefore, lubrication may be regarded as one of the secrets of successful compressor operation. In fact, in the air injection type of engine, the air compressor can probably be regarded as the heart of the system by virtue of the part it plays in bringing about combustion.

The air compressor as usually installed in higher powered Diesel engines will generally have either three or four stages, and will be

equipped with suitable intercoolers. The compression of air to pressures in the neighborhood of 1,000 pounds will of course develop a considerable amount of heat; it is the function of the intercoolers to reduce this heat and thereby keep cylinder temperatures down to minimize the extent of oil vaporization. This is of course in the interests of safety, for otherwise accumulations of dust and carbonaceous matter in the intercoolers, etc., might easily so restrict the air passages as to increase the velocity and consequently the frictional temperature of the air to a dangerous extent.

Deposits of Dirt and Carbon

While dirty air is perhaps one of the most general causes of such accumulations of foreign matter, we must not forget that an excessive amount of lubricating oil will tend to develop carbonaceous matter which will materially enhance the accumulation of deposits.

In addition an excess of oil fed to the compressor cylinders may bring about leaky valves due to a certain amount of the oil becoming carbonized on the latter. All this, of course, leads to a decrease in operating efficiency, for this carbonaceous matter being relatively sticky in the early stages of its formation, will also tend to adhere to the piston rings, thereby causing them to become inoperative; furthermore, it will tend to destroy the lubricating film and result in scored cylinders.

Unfortunately there is no oil which will not deposit some carbon; on the other hand, there is a surprising difference in the nature and quantity of this carbon which will be developed by different oils.

Consequently, not only must the oil be most carefully selected, but also, whatever its characteristics, the utmost care should be taken to prevent the use of more oil than is necessary.

In this respect it is very difficult for some operators to realize that but one or two drops of oil per minute is all that is necessary. This is effectively counteracted in many Diesel air compressors by so designing that the intermediate stage is at the bottom. As a result of such construction there is always a pressure opposing the tendency of the oil to work up into the air space from the lowest cylinder wall where it is thrown by the crankpin.

Air Cylinder Lubrication

To best effect air compressor cylinder lubrication, each cylinder should be equipped for force feed or pressure lubrication, whereby uniform and measured quantities of oil can be fed regularly; in the first stages, only a drop or two a minute will be necessary.

The third or last stage will usually be abundantly served with oil carried up from the preceding. On the other hand, no hard and fast rule can be laid down in this regard, and the safest course to follow in determining upon the quantity of oil to use is to remove the valves at periodic intervals and examine the cylinder walls. A properly lubricated wall should be coated with a film of oil which will just barely dampen or stain a cigarette paper.

Overheating and Flash Point

This matter of the heat due to compression has caused an unfortunate confusion in the minds of some operators as to the interpretation of the flash points of lubricating oils for air compressors.

Flash point readings are of value only in indicating the relative initial volatility of different oils, and are not definite temperatures at which they "boil" or go completely into vapor corresponding to the boiling point of water.

Oils of the proper consistency which leave unusually low carbon are much to be preferred to oils of high flash point. Certain engineers, however, in their eagerness to secure oils of high flash point will frequently overlook this matter of subsequent carbon deposits. This is, of course, erroneous.

Water

The possibility of development of moisture within an air compressor, especially when the engine is shut down, requires that an oil for such service be capable of developing and maintaining a tenacious water-resistant lubricating film. Such moisture is normally the result of condensation; in consequence, it may always be more or less expected.

To meet the above requirement, it is customary practice to compound many oils for Diesel engine air compressor service with a small percentage of high grade fatty oil, which will render the resultant product especially adherent to wet metallic surfaces. This will resist the washing-off effects of water, thus preventing rusting or corrosion of the walls as well as the pistons and rings.

CONCLUSION

In the preceding pages, we have endeavored to develop a descriptive picture of the Diesel engine with special attention to those factors which may affect the extent to which wear occurs. Emphasis has also been placed upon the operating conditions which should be studied. It is hoped that by this discussion a better understanding of Diesel engine operation will be brought about, and that it will be more clearly realized that repair work in general is very frequently due to insufficient recognition of the lubricating requirements.

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